PARTITIONED SOLUTION OF COUPLED PROBLEMS USING QUASI-NEWTON METHODS

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Coupled problems are composed of different sub-problems with equilibrium conditions at the interface which consists of the common boundaries of these sub-problems. Numerous techniques exist to solve these coupled problems in a partitioned way, which means using separate solvers for the different sub-problems. Several of these partitioned techniques impose boundary conditions for some variables at the interface and extract the value of other variables at this location. As these techniques do not require modification of the solvers, they treat them as black boxes. They typically enforce the equilibrium conditions on the interface by performing iterations.

In this work, the goal is to analyze and compare several of these coupling techniques for black box solvers, with a focus on quasi-Newton algorithms. The coupled problem of interest is fluid-structure interaction (FSI) although it has already been shown that several of the investigated techniques are also applicable to other coupled problems, many of them multi-physics problems but also coupling between sub-problems with similar physics.

Quasi-Newton techniques condense the coupled problem to a set of nonlinear equations with some of the variables at the interface as unknowns. They create an approximation for the (inverse of the) Jacobian of these equations using the values of the interface variables during the coupling iterations. These techniques are mainly advantageous when a von Neumann stability analysis on fixed-point iterations between the solvers indicates that only a small fraction of the wave numbers in the coupling error is unstable.

Currently, there are many quasi-Newton techniques, including algorithms using multiple grid refinements or multiple solvers. In addition, there are several techniques for the construction of the approximate (inverse of the) Jacobian. Multiple algorithms will be analyzed regarding mathematical properties and computational performance on test cases. Furthermore, they will be compared to relaxation algorithms.

Keywords: quasi-Newton, fixed-point, partitioned, multi-physics, fluid-structure interaction